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Estuarine, Coastal and Shelf Science 66 (2006) 459–467

ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ecss

Sources and transfer of organic matter in food webs of a Mediterranean coastal environment: Evidence for spatial variability

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Received 24 May 2005; accepted 3 October 2005
Available online 2 December 2005

Abstract

The spatial variability in the food web structure of a Mediterranean semi-enclosed coastal environment (Stagnone di Marsala, Italy) was investigated using stable carbon and nitrogen isotopes. Organic matter sources and consumers were sampled in two locations with different environmental features (e.g. hydrodynamic regime, open-sea influence, vegetal coverage). Overall more ^{13}C-enriched and ^{15}N-depleted values were found in the central location than in the southern for organic matter sources and consumers. Pelagic consumers (zooplankton and juveniles of transient fish) showed slight spatial differences and in both locations seemed to depend on phytoplankton as the ultimate energy source. In contrast, benthic consumers (epifauna and resident fish) exhibited remarkable differences between locations. Spatial differences in organic matter sources were smaller than in benthic consumers and thus consumers presumably exploited different ultimate organic matter sources in the two locations. Sedimentary organic matter and epiphytes appeared to be the main primary producers transferred within the food web in both locations, and seagrasses seemed to play a non-negligible trophic role in the central location. The results of this paper corroborate the finding food webs are characterised by high spatial variability even on a small spatial scale and environmental heterogeneity more than primary production that seems to influence the trophic role of autotrophs.

Keywords: carbon isotopes; nitrogen isotopes; food web; seagrass; spatial variability; coastal environment; Mediterranean

1. Introduction

Elucidating the trophic links in coastal ecosystems is a complex task but is one of the most important ways of understanding how they function. Coastal systems are characterised by high diversity and a large variety of primary producers such as vascular plants, macroalgae, benthic and pelagic microalgae. The fate of organic matter produced locally is often unrelated to the relative abundance of autotrophs and is subject to great variability (Cyr and Pace, 1993; Cebrián and Duarte, 1994, 1995). The relative importance of organic matter sources is linked to both the primary producer and the environmental features (Duarte and Cebrián, 1996). The thickness, growth rate, nutrient concentrations and chemical defences of primary producers all lead to much greater exploitation of micro- and macro-algae than that of higher plants (i.e. vascular plants) (Cebrián and Duarte, 1994). The degree of environmental exposure (e.g. the hydrodynamic regime) can also influence the trophic role of primary producers in coastal systems (Deegan and Garritt, 1997).

Comparing coastal and estuarine food webs it can be argued that hydrology (tidal range, sea vivification, upland terrestrial inputs) affects both the production and availability of primary producers, and thus their contribution to the diets of consumers (Sullivan and Moncreiff, 1990; Deegan and Garritt, 1997). As a consequence, the magnitude of exploitation of each food resource in complex environments is difficult to assess, being highly site-specific.

The relative proportion of various primary producers assimilated by consumers has been assessed in several marine

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doi:10.1016/j.ecss.2005.10.004

ecosystems using the powerful tool of carbon and nitrogen stable isotope analysis (see Fry, 1984, 1988; Hemminga et al., 1994; Lepoint et al., 2000; Pinnegar and Polunin, 2000; Vizzini et al., 2002). Application of this technique is based on the assumption that with increasing trophic levels, stable isotope changes follow a predictable fractionation (Gannes et al., 1997). In consumers trophic shift for carbon is typically low (about +0.3‰ for consumers analysed whole and +1.3‰ for consumers analysed as muscle) (McCutchan et al., 2003), while for nitrogen it is higher (about +1.4‰ for consumers feeding on invertebrate diets and +3.3‰ for consumers feeding on high-protein diet, about +2.6‰ for carnivorous fish) (McCutchan et al., 2003; Vanderklift and Ponsard, 2003). In complex environments with a relatively large number of potential sources, estimation of the contribution of each source to the food web can be ambiguous. The isotope technique can be effectively used to trace organic matter flow within food webs only when major categories of primary producers show distinct isotope ratios, which can be compared with ratios in consumers to infer about the role and importance of a single source or a combination of sources.

This paper examines the fate of organic matter sources in a coastal basin in the western Mediterranean (Stagnone di Marsala, Italy) using carbon and nitrogen stable isotopes as tracers. Some isotopic studies were carried out previously within the Stagnone di Marsala to evaluate the trophic structure in a *Posidonia oceanica* meadow from the central region of the basin (Vizzini et al., 2002), and the trophic ecology of individual species such as the sand smelt *Atherina boyeri* (Vizzini and Mazzola, 2002, 2005) and pipefish *Syngnathus abaster* and *Syngnathus typhle* (Vizzini and Mazzola, 2004) from a *Cymodocea nodosa* bed. Since spatial differences were formerly recognised for several environmental variables within the Stagnone [e.g. depth, hydrology (Sarà et al., 1999), vegetal coverage (Calvo et al., 1996), quality and quantity of suspended and sedimentary organic matter (Mazzola et al., 1999; Pusceddu et al., 1999; Sarà et al., 1999)], the aim of this paper was to verify whether the fate of organic matter sources, and hence trophic structure, also change on a spatial scale comparing food webs from both the central and southern regions of the Stagnone. In detail, the main goal was therefore to assess the spatial differences in the trophic role of the main organic matter sources, using dual stable isotope analysis (δ^{13}C and δ^{15}N) of animals and their potential food resources.

2. Materials and methods

The Stagnone di Marsala (37°52′N, 12°28′E) is a shallow coastal basin (surface area of 20 km^2; average depth of 1 m) in western Sicily (Italy, western Mediterranean) (Fig. 1). It is connected to the Mediterranean Sea by two channels, one to the north (400 m wide, 0.3–0.4 m deep), the other to the south (1200 m wide, 1.0–1.5 m deep). The Stagnone is oligotrophic [chlorophyll-*a* values approximately 1.0 μg l^{-1} (Sarà et al., 1999) and 3.0 μg g^{-1} (Pusceddu et al., 1999), respectively in the water column and sediment] and is influenced very little by terrigenous organic matter as minimal freshwater input is present.

The northern and central regions of the basin are influenced little by the open sea; dominant northern winds and shallow depth result in frequent resuspension events (Pusceddu et al., 1999; Sarà et al., 1999). In contrast, the southern part is influenced by open-sea vivification and sedimentation processes are prevalent because of its greater depth and vegetal coverage (Pusceddu et al., 1999; Sarà et al., 1999). The bottom is characterised by sandy–muddy sediments and covered by *Cymodocea nodosa*, the dominant macrophyte. *Caulerpa prolifera* is associated with *C. nodosa* mainly in the northern and central regions, while a regressing *Posidonia oceanica* meadow is present exclusively in some parts of the central and southern regions (Calvo et al., 1996).

The study was carried out seasonally throughout 1999, with samplings performed in the southern and central regions of the Stagnone (hereafter Locations A and B, respectively) (Fig. 1). Particulate organic matter (POM) was filtered from 2-L samples of seawater. Each sample was filtered onto precombusted (450 °C, 4 h) Whatman GF/F filters in the laboratory. Phytoplankton was not sampled in this study because the shallow depth and resuspension determined large quantities of non-autotrophic components in the suspended organic matter (Pusceddu et al., 1999; Sarà et al., 1999). Phytoplankton signatures were taken from literature isotopic data for POM collected in the open sea adjacent to the Stagnone (Mazzola et al., 1999). Sedimentary organic matter (SOM) was sampled by collecting sediments with hand corers, and processing the top 1 cm for isotopic analysis. Benthic primary producers (macroalgae and seagrasses) were collected by hand. Seagrass leaves and algae fronds were analysed after gentle scraping to remove the epiphyte component, which was analysed separately. Pooled samples were analysed for macrophytes.

During the spring, when primary production in the study site is higher (Sarà et al., 1999), samples of benthic microalgae were collected on glass slides anchored above the sea bed at each site. The slides were collected weekly and kept in cold seawater. In the laboratory each slide was scraped under a binocular microscope, with special care taken to ensure that samples were free of debris. Each composite sample containing material collected from up to 30 slides was filtered onto a precombusted (450 °C, 4 h) Whatman GF/F filter.

Zooplankton was sampled by towing a net (mesh size: 125 μm) for approximately 10 min. Small invertebrates associated with the vegetation (epifauna) were caught with a hand-towed net (mesh size: 400 μm). Zooplankton and epifauna samples were sorted under a binocular microscope with forceps and isolated to remove detrital material. Invertebrates were analysed whole and each sample obtained by pooling a large number of individuals (generally >100). Fish were sampled using a small hand-towed trawl net (length: 3.5 m; mesh size: 3 mm). Only muscle tissue from the dorsal region was used for isotopic analysis due to the lower variability in isotopic composition compared to other body parts (Pinnegar and Polunin, 1999). Composite samples were analysed to avoid inter-individual differences in the isotopic composition.